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COLOR CHARACTERISTICS OF LOW-MELTING CLAYS

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An unconventional method of determining the color of clay and ceramic materials in air-dry and calcined states in equal-color coordinates of the color space using the color characteristics (saturation, hue, yellow hue, lightness, color coordinate) is employed to classify clays from the Gzhel' deposit. The method is recommended for adjusting the color range of ceramic articles.

Under the present production conditions for domestic-use ceramics, together with the traditional quality indicators (whiteness, translucence, and so forth), it has become necessary to make a quantitative evaluation of the color and the hues of a colored ceramic article. Manufacturers still use qualitative methods to evaluate ceramic articles and the color of the ceramics. Subjective evaluations of the color of a ceramic are made with a certain error. In this connection there is need for a quantitative characteristic for the color of clay and ceramic materials.

It is known that clay rocks are characterized by a natural color. Investigations of clays by Mössbauer spectroscopy have shown that the compounds of iron — the main chromophore in these rocks — produce their color which depends on the valence, coordination number, and nearest-neighbor environment of the central complexing ion and the character of the distortion of the coordination polyhedron. The color of rock itself depends on the different color phases and their quantitative content present in it [1].

Nuclear magnetic resonance studies of the effect of iron on the color of clay minerals have established that the change in the red color depends on the content of hematite and goethite in clay, although other iron-containing minerals, which have no effect on the color of clays, could also be present [1]. In addition, the absence of chromophoric minerals — hematite and goethite in clay — makes the clays lighter in color, i.e., it results in the appearance of gray, green, and pistachio colors.

The dependence of the whiteness of porcelain on the change of the color coordinate in the CIE system $L^*a^*b^*$ was determined in [2], which is devoted to the investigation of the dependence of the color of porcelain on the content of iron compounds and the mineral composition of the clay rock.

It is known that the human eye detects a color change only if the change is above a so-called color threshold (minimum visually detectable color change) or the color difference index ΔE . The technology used in modern spectrophotometers makes it possible to determine this quantity from the relation

$$\Delta E = \sqrt{(L-L')^2 + (a-a')^2 + (b-b')^2},$$

where L , a , and b are the color coordinates of a standard sample and L' , a' , and b' are the color characteristics obtained from measurements.

Clays from the Gzhel' deposit, which contain hematite and goethite, represented by bright- and dark-colored samples, were chosen to study the color characteristics of low-melting clays. These clays were used to compact 50 mm in diameter and 10 mm high samples. The color of the experimental clays was measured with a "Pul'sar" spectrocoulometer at the G. V. Plekhanov Academy of National Economics. Colored paper was used as a color standard.

These investigations gave the color characteristics of low-melting air-dry and calcined Gzhel' clays in the CIE system $L^*a^*b^*$.

The results obtained show that Gzhel' clays in the air dry state can be fall into the following groups.

Light-colored clays, which include pistachio, green, and gray clays as well as an interlayer of multicolored clay, form one group. These clays are distinguished by high lightness L — from 68.0 to 75.0, low yellow hue G — from 21.0 to 32.5, negligible color saturation S — in the range 8.7–15.7, and high hue H indicators — from 92.6 to 96.3. The color coordinates of the clays investigated were as follows: a^* (–0.392) ... (–1.556) and b^* (–8.7) ... 15.7.

Dark-colored clays—red, grown, red-brown — form another group. These clays are characterized by low lightness

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TABLE 1.

Sample	CIE color coordinates <i>Lab</i> , 1976						MKO color coordinates, 1931						Yellow hue <i>G</i>		Saturation <i>S</i>		Hue <i>H</i>	
	<i>L</i>		<i>a</i> *		<i>b</i> *		<i>X</i>		<i>Y</i>		<i>Z</i>							
	in dry state	in calcined state	in dry state	in calcined state	in dry state	in calcined state	in dry state	in calcined state	in dry state	in calcined state	in dry state	in calcined state	in dry state	in calcined state	in dry state	in calcined state	in dry state	in calcined state
Clay:																		
No. 14 gray	73.37	76.53	−0.88	8.95	9.48	33.31	44.52	53.25	45.75	50.87	44.56	30.16	21.33	72.10	9.61	34.56	95.30	75.25
No. 6 pistachio	68.40	78.85	−0.39	5.53	8.70	26.31	37.64	55.80	38.52	54.68	37.82	38.19	21.01	56.67	8.71	21.71	92.65	74.04
Interlayer No. 12 gray	70.67	66.61	−1.07	13.12	9.69	29.00	40.54	39.47	41.71	36.13	40.29	21.52	22.01	76.65	10.75	31.85	90.24	65.70
Clay:																		
No. 8 green	75.81	63.79	−1.56	20.11	15.71	37.10	48.04	37.83	49.59	32.55	42.83	14.97	32.50	100.03	15.79	42.52	95.71	60.49
No. 18 multicolored with gray	60.05	57.04	8.09	20.53	17.12	28.44	29.74	29.62	28.20	25.00	21.92	13.69	52.72	93.56	18.94	34.75	64.63	53.37
No. 16 multicolored with green	57.44	57.01	11.16	20.43	20.06	28.92	27.66	29.63	25.50	25.04	18.02	13.60	64.96	93.86	23.11	35.29	61.62	54.55
No. 20 red-brown	56.92	55.14	12.54	21.61	21.00	27.84	27.39	24.71	24.85	23.05	16.97	12.57	68.75	96.10	24.46	34.87	59.16	51.51
No. 3 lilac	62.37	58.93	9.14	19.28	14.80	28.81	32.75	31.45	30.84	26.97	25.72	14.94	47.54	90.58	17.40	35.00	58.32	54.88
No. 13 red	55.00	54.72	15.71	23.42	23.80	27.69	26.12	27.69	22.93	22.68	14.16	11.69	80.34	101.55	28.52	37.45	56.57	51.74
No. 10 brown	52.19	51.96	15.79	21.60	23.10	24.22	23.31	24.43	20.32	20.14	12.45	11.87	81.77	92.81	27.99	32.46	55.57	48.25
Paste No. 21: red-brown clay — 50% gray interlayer — 30%	56.73	56.72	11.10	19.28	17.61	27.13	26.88	28.90	24.74	24.66	18.66	14.02	60.03	89.87	Not determ.	33.29	Not determ.	54.60
Paste No. 22: red-brown clay — 70% gray interlayer — 30%	56.05	53.59	11.49	20.40	18.00	24.85	26.21	25.81	23.99	21.60	17.75	12.71	61.69	90.51	Same	32.20	Same	50.51
Paste No. 23: red-brown clay — 90% gray interlayer — 10%	53.35	52.31	14.47	21.60	20.05	25.06	24.12	24.76	21.35	20.42	14.54	11.76	72.41	94.06	"	33.09	"	49.22
Kaolin	91.94	Not determ.	−0.87	Not determ.	5.78	Not determ.	78.53	Not determ.	80.56	Not determ.	86.55	Not determ.	10.89	Not determ.	5.85	Not determ.	98.58	Not determ.
Standard: barytic plate (white)	97.57	—	−0.79	—	0.16	—	91.54	—	93.84	—	110.56	—	0.01	—	0.80	—	168.33	—
Paper:																		
red	56.10	—	44.93	—	24.23	—	35.29	—	24.01	—	14.79	—	122.82	—	51.05	—	28.34	—
dark-orange	59.19	—	49.79	—	39.86	—	40.98	—	27.23	—	10.68	—	151.07	—	63.78	—	38.68	—
violet	51.12	—	45.40	—	−18.42	—	29.41	—	19.37	—	35.63	—	0.68	—	49.00	—	337.92	—
yellow	84.64	—	−4.76	—	79.23	—	61.92	—	65.30	—	12.37	—	101.30	—	79.38	—	93.44	—
green	71.73	—	−40.50	—	29.65	—	30.19	—	43.26	—	26.55	—	24.26	—	50.19	—	143.79	—
blue	32.96	—	−1.06	—	−20.31	—	7.26	—	7.52	—	16.96	—	115.42	—	20.33	—	267.02	—
light-brown	55.70	—	12.74	—	25.96	—	26.12	—	23.61	—	13.75	—	79.92	—	28.92	—	63.86	—
dark-brown	38.16	—	3.22	—	2.47	—	10.40	—	10.18	—	11.09	—	15.22	—	4.06	—	37.46	—

(52 – 56), high yellow hue (68.7 – 81.7), and high color saturation (12.5 – 15.8). The hue indicators lie in the range 55.5 – 59.2, and the color coordinates correspond to a^* 12.5 – 15.8 and b^* 21 – 24.

Multicolored and lilac-colored clays can be conventionally called intermediate clays. Clays with lightness 55 – 57, yellow hue 47 – 65, color saturation 17.4 – 23.0, and hue indicator 58.3 – 64.6 should be put into this group. The color coordinates are a^* 8.0 – 9.1 and b^* 15.0 – 17.1.

It is evident that the color characteristics of uncalcined clays, specifically, the color hue and saturation, depend on the natural color of the clay. Thus, in the air-dry state the hue of light-color clays reaches the maximum values (up to 100) and for dark-colored clays and clays in the so-called intermediate group the hue is 50 – 60. However, the color saturation, in contrast to the hue, is characterized by low values: for light-colored clays — 8.7 – 15.7 and for dark-colored clays — 12.5 – 23.0.

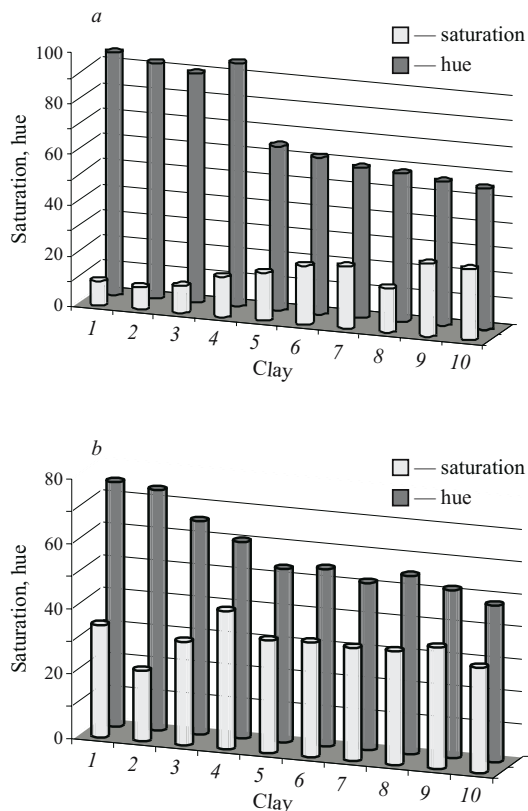


Fig. 1. Variation of the color hue and saturation in Gzhel' clays in the air-dry state (a) and calcined at 980°C (b): 1) gray No. 14; 2) pistachio No. 6; 3) gray interlayer No. 12; 4) green No. 8; 5) multicolored with gray No. 18; 6) multicolored with green No. 16; 7) red-brown No. 20; 8) lilac-colored No. 3; 9) red No. 13; 10) brown No. 10.

The color saturation, hue, and other color characteristics of Gzhel' clays are presented in Fig. 1. The color coordinates of Gzhel' clays in the air-dry state and calcined at 980°C are presented in Table 1.

Red-brown clays had the maximum color saturation (see Fig. 1).

It can be asserted on the basis of an analysis of the color characteristics of clays that the air-dry light-colored clays from the Gzhel' deposit have high lightness and hue, low

color saturation and yellow hue, and their color coordinates in the CIE system $L^*a^*b^*$ are negative. As the natural color of the clays changes from light to dark-red tones their color saturation increases, and as their hue intensity decreases the clays are characterized by low lightness. High yellow hue indicators in the color coordinates are positive.

As a result of calcination at 980°C the light-colored Gzhel' clays (gray, pistachio, gray interlayer, green) acquire a red hue of different tonality. Color measurements performed on samples of these clays have shown that the hue indicator decreases appreciably when the color saturation increases sharply. The color (red, brown, red-brown) and dark-colored (multicolored, lilac-colored) clays acquire a red and bright-red color after calcination. The hue indicator decreases, and the color saturation sharply increases (see Fig. 1).

Thus, calcination of Gzhel' clays changes the color characteristics, i.e., engenders an overall decrease of the hue indicator, a sharp increase of the color saturation and yellow hue, which is reflected in a color change of all samples and, in addition, the their color changes to red with different tonality.

The color characteristics of low-melting clays (color saturation and hue, yellow hue, lightness, color coordinates) make it possible to identify the color of clays and ceramic pastes in the air-dry and calcined states. The highest hues and lowest color saturation and yellow hue are characteristic for light-colored clays with red colors with different tones and ceramic pastes are characterized by high color saturation and yellow hue with an appreciable decrease of the hue indicator.

In conclusion, we note that determination of the color in equal-contrast coordinates in color space makes it possible not only to classify clays and ceramic materials on the basis of their color characteristics but also to adjust the color range of ceramic articles.

REFERENCES

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